Notes on some Photographs taken with a Visual Telescope.

By H. F. Newall, M.A.

During the past six months several photographs of stars, &c., have been taken with the Newall telescope of the Cambridge Observatory with a view of testing the performance in photographic work of a large telescope constructed for visual work. I beg leave to show to the Society some of the results obtained.

These results may best be set forth if I describe the individual photographs exhibited, explaining at the same time the object aimed at in each attempt. The experiments have been made at considerable intervals, whenever, for some reason or another, spectroscopic work was not possible or convenient. Hence the information has been gathered slowly and under very varied conditions (as to temperature, &c.)

Some details are here given concerning the instrument, since a knowledge of them is necessary to a discussion of the images obtained:

Aperture of the object-glass	24·8 inches	630 mm.
Focal length	29 ft.	8844 mm.

Ratio focal length ÷ aperture = 14·04

The crown and flint lenses are separated only by the thickness of tinfoil.

Details concerning the colour correction of the object-glass:

	Inch.	Millimetre.	
[H_α (C)	− ·050	− 1 25 added April 23]	
Minimum between D and *b*	− ·159	− 4·04	Mean of 6 determinations made in course of 2 years with different slit spectroscopes by the Harkness-Vogel method.
H_β (F)	·000	·000	Deduced from photographs of the spectrum of *Polaris* taken with objective prism in front of object-glass; aperture used 10½ inches.
H_γ (G′)	+ ·45	+ 11·4	
H_δ (*h*)	+ 1·07	+ 27·2	
H_ϵ (H_1)	+ 1 50	+ 38·1	
H_ζ (Huggins' α)	+ 2·25	+ 57·2	

Note.—Many slightly discrepant determinations have been made of the chromatic aberration in the red, yellow, and green. The sources of discrepancy are not yet perfectly clear, but there are indubitable signs of a temperature coefficient of considerable importance. The separation of minimum and H_β foci given above is therefore to be regarded as provisional. In the appearance of star images on warm and cold nights the differences of the colour correction are quite noticeable in careful observation.

To facilitate comparison with other large refractors I append the following table:

Line and Wave-length.	Vienna Telescope.			Pulkowa Telescope.			Lick Telescope.			Newall Telescope.		
	df	$\frac{h}{f}$	$\frac{df}{f} \times 10^5$	df	$\frac{h}{f}$	$\frac{df}{f} \times 10^5$	df	$\frac{h}{f}$	$\frac{df}{f} \times 10^5$	df	$\frac{h}{f}$	$\frac{df}{f} \times 10^5$
	mm.			mm.			mm.			mm.		
H_α (C) 656	2·7	·000017	26	3·0	·0000115	21	5·3	·0000162	31	3·1	·0000250	35
D 589	0·0	·000	0	0·0	·000	0	0·0	·000	0	0·0	·000	0
H_β (F) 486	6·0	·0000378	58	6·4	·0000245	45	11·4	·0000349	66	4·0	·0000323	45
H_γ (G′) 434	23·5	·0001478	227	32·9	·0001258	233	48·3	·0001471	281	15·4	·0001243	174
H_δ (h) 410	...	...	...	...	...	...	81·5	·0002484	474	31·2	·0002518	353
Aperture	27 in. 675 mm.			30 in. 762 mm.			36 in. 914 mm.			24·8 in. 630 mm.		
Focal length	34 ft. 10,360 mm.			46 ft. 14,120 mm.			$56\frac{1}{2}$ ft. (?) 17,200 mm.			29 ft. 8,844 mm.		
Ratio $\frac{\text{F. L.}}{\text{Ap.}}$	15·3 : 1			18·5 : 1			19·1 : 1			14·0 : 1		
Glass cast by	Feil			Feil			Feil			Chance		
Glass worked by	Grubb			Clark			Clark			Cooke		
Date	1881			1883			1886			1868		

[*Note added April* 23.—The numbers given for the Newall telescope are based, so far as the visual part of the spectrum is concerned, on determinations made under very favourable conditions on April 21. The temperature in the dome at the time was 38° F. (3°·3 C).]

Plate No. 1.—For a study of the chromatic aberration of the object-glass in the region of the foci for violet and ultra violet light.

1894 March 29. 8.33–10.11. Spectrum of *Polaris*.

Plate: Edwards's instantaneous isochromatic.

South Kensington objective prism, $10\frac{1}{2}$ inches aperture, mounted in front of the central part of the object-glass of the equatorial.

Nine exposures, 10 minutes each, with change of focus between successive exposures by first three equal movements of $\frac{3}{16}$ inch from visual focus, and lastly five equal movements of $\frac{3}{8}$ inch up to $2\frac{1}{4}$ inches from visual focus.

The driving clock of the equatorial was so rated that the spectrum did not trail on the plate, as in the usual method adopted in photographing spectra with an objective prism. Thus the width of the spectrum in that region which was in focus on the plate was very small. The width in the narrowest part near H_δ (*h*) at focus +1 inch was found by measurement to be 2″·14 (0·092 mm.).

The plate shows very clearly the travelling of the focussed part of the spectrum from the yellow to the violet end of the spectrum, as the plate is drawn out further and further. The method gives good reliable results between H_β (F) and the ultra violet, but not in the green and yellow. The line H_β (F) forms, however, an excellent connecting link between determinations made in the method above described and the usual spectroscopic method due to Harkness and employed by Vogel and others.

From this plate the results given in an earlier paragraph were deduced.

Plate No. 2.—For a study of the spherical aberration of the object-glass.

1894 March 29. 12.10–12.45. *Polaris.*

Plate: Edwards's instantaneous isochromatic.

Screen: Dark yellow glass.

Nine exposures: three for central circular aperture, 6 inches in diameter, for 2 minutes each—one at the visual focus, the other two at $+\frac{3}{16}$ inch and at $-\frac{3}{16}$ inch; three for exterior annulus, with external radius 12 inches, and with internal radius $11\frac{1}{2}$ inches, for 2 minutes each, with same focussing as in the first case; three more with the same annulus and focussing, but with 3 minutes' exposure.

The images are very satisfactory in both cases, and careful comparison shows that the images at that focus which was called "visual," and which was determined with 24 inches aperture,

are distinctly better than the images obtained either $\frac{3}{16}$ inch inside or $\frac{3}{16}$ inch outside that focus.

Though the areas of the central and annular apertures are in the ratio of 9 to 12, still the plate shows that while an exposure of 2 minutes is enough for the central aperture, an exposure of 3 minutes is hardly enough to give comparable images with the (larger) annular aperture.

Inspection of the images with an eye-piece makes clear the need for the longer exposure when the annulus is used. The effect of atmospheric tremor is to give rise to rays round the central image. The rays are in constant movement round the centre, sometimes long (10″), sometimes short (2″); they are therefore not the result of defect in the glass, but are due to a momentary annulling of the contribution of disturbance which should come from some part of the annulus, but which, from those atmospheric causes that give rise to "bad seeing," is suppressed, leading to an upset of that balance necessary by the principles of the undulatory theory of light to the formation of a perfect image. In consequence of these moving rays, the light which in perfect conditions of seeing would be concentrated within a very small area is generally spread over different parts of an area having a diameter of 20″ or 30″, and is only for a moment now and then collected into a circular disc without the constantly moving rays.

Plate No. 3.—For a study of the effect of change of focus on the size and appearance of the photographic image of a bright star.

1894 January 18. 10.30–10.50. *Procyon.* (Mag. Oxon. Uranom. 0·5)

Plate: Wratten and Wainwright, "drop shutter."

No screen.

Thirteen exposures, thirty seconds each, with change of focus between successive exposures, by equal movements of $\frac{3}{16}$ inch from visual focus to a focus $2\frac{1}{4}$ inches outside the visual focus.

Focus.	Appearance of Image.
"Visual"	Blurred image about 100″ diameter, with ragged edge; increasing density to the centre; no defined nucleus.
(50) + $\frac{3}{16}$ inch	Smaller diameter, but similar to last.
(100) + $\frac{3}{8}$,,	,, ,, distinct nucleus now appears.
(150) + $\frac{9}{16}$,,	Similar to last; smaller diameter.
(200) + $\frac{3}{4}$,,	,, ,, diameter about 60″.
(250) + $\frac{15}{16}$,,	Smaller diameter; small disc within the ragged edge; defined nucleus.
(300) + $1\frac{1}{8}$,,	Ragged edge disappearing; disc increasing; nucleus still defined.
(350) + $1\frac{5}{16}$,,	No ragged edge; disc, 43″·8 in diameter; defined nucleus. Smallest image.

From this point onwards the appearance does not change; the diameter steadily increases; edge, comparatively speaking, clean cut; nucleus quite definite. Diameter at $2\frac{1}{4}$ inches about 100″.

The plate also has on it images of Bird's double ($0''\cdot8$), which is equivalent to a star of about the 8th magnitude. The appearance of the image hardly changes at all. It may be described as a small nucleus with ragged edge about $8''$ or $10''$ in diameter. The most intense nucleus is that at focus $+1\frac{1}{8}$ or $+1\frac{5}{16}$ inch.

Further, a small image of an 11th magnitude star is seen on the plate.

From the chromatic aberration curve deduced from the photographs of the spectrum of *Polaris* it appears that the best image on the plate now under consideration is that formed when the plate is placed at the focus for H_δ (*h*); a result which falls in completely with expectation based on a knowledge of the curve of sensitiveness of the photographic plates used, and the distribution of the foci for different wave-lengths along the axis of the equatorial.

The undulatory theory demands that with a perfectly figured object-glass the intensity of light at the centre of the diffraction pattern should be proportional to the fourth power of the aperture. Whilst it is improbable that practically this can be fulfilled, still it appears that the existence of the nucleus in the image is connected with this concentration of light in the focussed image amidst the superposed circles of aberration of the light coming from foci behind and before the plate.

Plate No. 4.—For a study of the applicability of dry collodion plate.

1894 February 3. 13.10–13.55. *Procyon.*

Plate: Hill Norris. Dry collodion, yellow label.

No screen.

Full aperture.

Twenty-five exposures: five exposures, $\frac{1}{4}^m$, $\frac{1}{2}^m$, 1^m, 2^m, and 4^m at each of the following focussings: visual, $+\frac{3}{16}$ inch, $+\frac{3}{8}$ inch, $+\frac{9}{16}$ inch, $+\frac{3}{4}$ inch.

Good small images about $5''$–$10''$ diameter are got of the bright star (mag. 0·5); but the image of an 8th magnitude star only begins to be visible on the plate after 4 minutes' exposure. The best image is got with focus $+\frac{3}{8}$ inch, that is, at the focus of light with wave-length intermediate between H_β (F) and $H\gamma$.

Plate No. 5.—For a study of the appearance of star images on an isochromatic plate, a light yellow screen being used; also for a study of the change of appearance of such images with varied exposures.

1894 January 23. 9.49–10.43. *Procyon* (mag. 0·5).

Plate: Edwards's instantaneous isochromatic.

Screen: Light yellow screen.

Aperture: full, 25 inches.

Twenty-five exposures: five at visual focus with the following exposures: $\frac{1}{4}^m$, $\frac{1}{2}^m$, 1^m, 2^m, 4^m; five similar exposures at

each of the following focussings: $+\frac{3}{8}$ inch, $+\frac{3}{4}$ inch, $+1\frac{1}{8}$ inch, $+1\frac{1}{2}$ inch.

The most definite "discs" are got at the focus $+\frac{3}{4}$ inch. There is no ragged edge; the disc does not increase much in size with lengthened exposure. The following measures were made of the discs of *Procyon* at focus $+\frac{3}{4}$ inch:

Exposure	$\frac{1}{4}^m$	$\frac{1}{2}^m$	1^m	2^m	4^m
Diameter	$33''.32$	$34''.02$	$34''.25$	$34''.48$	$35''.65$

Probably the best focus for a photograph intended for measure of images of neighbouring bright and faint stars would be $+\frac{3}{8}$ inch. An 8th magnitude star shows well with an exposure of $\frac{1}{4}^m$; the diameter of the image is about $3''$, and though the edge is not very definite, bisection with a micrometer wire would be easy. In none of the twenty-five exposures does the image of the 8th magnitude star exceed $5''$ in diameter. The images at visual focus are the best. But, as has been stated above, for measures of bright *and* faint stars the images at focus $+\frac{3}{8}$ inch would probably prove best.

Plate No. 6.—For a study of the effects of diminishing the circles of aberration by cutting down aperture; and for a trial of medium sensitiveness in isochromatic plates.

1894 April 4. 11.10–12.24. *β Geminorum* (mag. 1.36).

Plate: Edwards's medium isochromatic.

Screen: Light yellow glass.

Twenty-four exposures: five exposures with 24-inch aperture, $\frac{1}{4}^m$, $\frac{1}{2}^m$, 1^m, 2^m, and 4^m, at each of the following focussings: $\frac{3}{16}$ inch, visual, $+\frac{3}{16}$ inch; five exposures with 12-inch aperture durations as above, all at $+\frac{3}{16}$ inch focus; four exposures with 12-inch aperture, durations 1^m, 2^m, 4^m, 8^m, all at visual focus.

The images obtained with the smaller aperture are excellently good discs, but so small for so bright a star as *β Geminorum* (Mag. Oxon. Uranom., 1·36) as to make one fear that long exposures would be needed for fainter stars.

Plate No. 7.

1894 March 23. 11.35–11.45. *Castor.*

Plate: Edwards's instantaneous isochromatic.

Screen: Dark yellow glass.

Plate set at the visual focus behind a Thornton-Pickard spring shutter.

Twelve exposures: longest 8 seconds, shortest 2 seconds.

The images of the two components are in all cases distinctly separated, and are easily measurable discs of small dimensions. The seeing at the time the plate was exposed was fair. The position angle is, even in casual inspection, obviously different in the different exposures; a fact which must be attributed to atmospheric tremor. No measures of the position angle

have been made, but the following results of measurement of the separation of the centres are of interest. Five bisections of each component in each pair were made.

Exposure.	6 sec.	4 sec.	2 sec.	4 sec.	6 sec.	8 sec.
Distance	5″·71	5″·75	6″·01	5″·66	5″·78	5″·52
Probable error	±0·0061	±0·0103	±0·0063	±0·0065	±0·0097	±0·0082
Character of image	good round disc	good round disc	small star, faint, but easily seen	elongated discs	bad shape; triangular	round with small excrescence on one side

Diameters of star images in the exposure of 8 seconds:

Large star (single reading of each edge)	4″·03
Small star ,, ,, ,, ...	2·56
Separation of nearest edges	2·51
Deduced separation of centres	5·805

There is evidence of diminution of measured separation with increased exposure. Such diminution is what one would expect from the fact that each component falls on a part of the plate already illuminated by the other component, with the result that the image of each component grows more rapidly on the side near to the other component than on that remote from it. In bisecting the images with the micrometer, a false centre is taken.

The effects of the chromatic aberration of such a telescope as the 25-inch equatorial at Cambridge make themselves felt very markedly in spectroscopic work in a way that hardly needs explanation. If the slit of a spectroscope, put on at the eye-end, is adjusted to be in the focus for H_β light, the circle of aberration on the slit for H_ϵ light is so considerable that but a very small percentage of H_ϵ light gets into the spectroscope. To obviate this difficulty in a way that would in other ways be advantageous, I have had a simple lens made, which, being set in the cone of rays converging from the object-glass of the equatorial to the focus at about 5 feet from that focus, should, by being chromatically uncorrected, just correct the over-corrected object-glass. In this way the separation of the H_β and H_ϵ foci is reduced from 1·5 inches to about two-tenths of an inch, and, but for some mistake made in the working of the lens, the correction would have been more satisfactory even than it is, and I hope shortly to have the more perfect correction made.

The focal length of the combination is shorter by about 18 inches than that of the object-glass alone. It is necessary, therefore, to arrange that the collimator of the spectroscope is

pushed up into the equatorial tube, and space is thus economised and strength gained; and the alteration of ratio of focal length to aperture is one which only brings convenience with it. The correction thus obtained gives very satisfactory results in spectroscopic work.

In having the lens made I intended also to see whether the resulting image could be enlarged by an enlarging camera attached to the equatorial, and had hoped that satisfactory enlargements of planets might thus be obtained, inasmuch as in such work the field is small.

I have made several attempts to photograph *Jupiter*, and have hitherto got results that do not satisfy me. The failure I attribute in part to the difficulty of the subject—the detail is very fine—in part to unfavourable atmospheric conditions, and in part to the imperfection of the correcting lens. I have pleasure in exhibiting to the Society a slide showing the sort of result obtained. In order to test the performance of the enlargement apparatus on other objects, and for the sake of being able more easily to focus the camera, I have taken some enlargements of lunar craters with the same arrangement. Of these also I exhibit slides. The plates on which the originals were taken are Edwards's instantaneous isochromatic; a light yellow glass was used as screen, and the enlargement of the corrected image is sixfold.

The Star Cluster 3315 (*Cape Observations*).

By H. C. Russell, B.A., F.R.S.

The remarkable discovery by MM. Henry of a nebulous background to the *Pleiades* induced me to experiment with the same object in view on the finest of our southern star clusters, which Herschel describes as "the most brilliant object of the kind I have ever seen"; "a glorious cluster of immense magnitude, being at least two fields each way"; and in another place (two or three fields each way), "the stars are 8, 9, 10, and 11 magnitudes, but chiefly of the tenth, of which there must be at least 200."

Three photographs have been taken with a view of finding out if there existed any nebulous light amongst the stars of this magnificent cluster. The first was taken on 1893 April 11, and was exposed in the star camera $7\frac{1}{2}$ hours. On it there is not the slightest sign of any nebulous background, although the plate has recorded in the square degree in which the cluster stands no fewer than 12,702 stars. The second was taken on April 12, and was exposed for $6\frac{3}{4}$ hours. The night was better than that of the 11th, and as a consequence the plate shows 14,551 stars in the same square degree, and on this also there is